The Finnish Environment

217

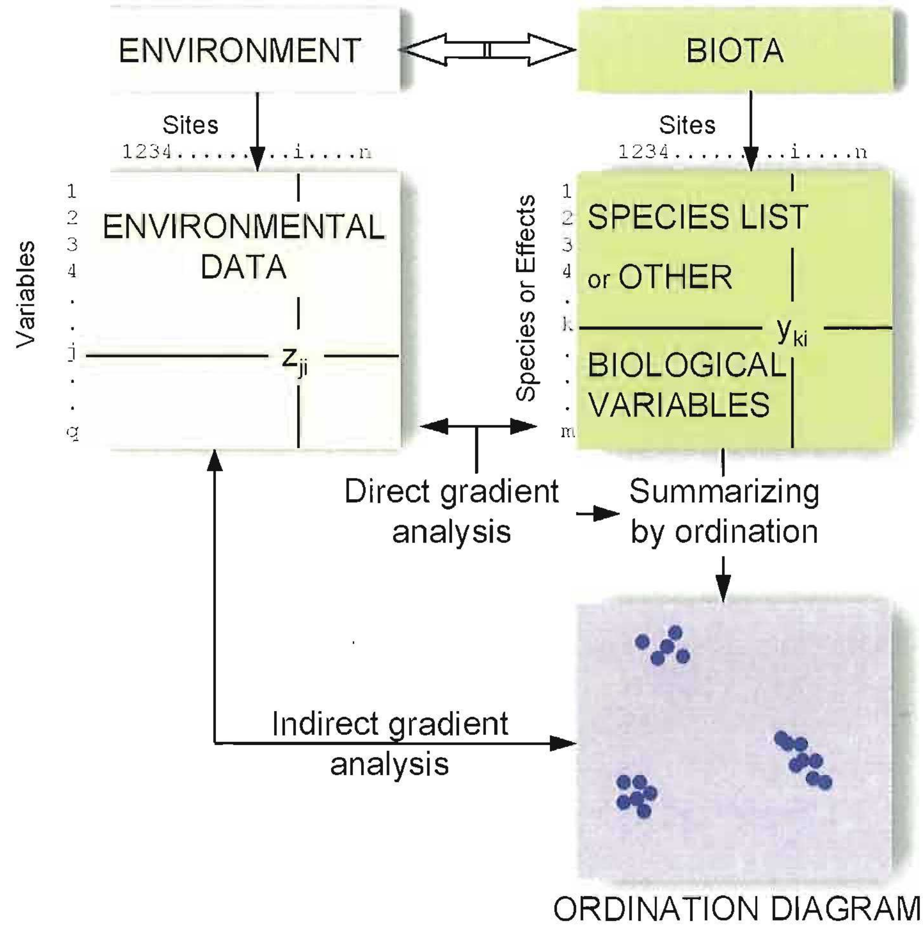
INTERNATIONAL COOPERATION

Sirpa Kleemola and Martin Forsius (eds)

7th Annual Report 1998

UN ECE Convention on Long-Range Transboundary Air Pollution

International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems



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Contents

Preface

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The Integrated Monitoring Programme (ICP IM) is part of the Effects Monitoring Strategy under the UN ECE Long-Range Transboundary Air Pollution Convention. The main aim of ICP IM is to provide a framework to observe and understand the complex changes occurring in the external environment. The monitoring and prediction of complex ecosystem effects on undisturbed reference areas require a continuos effort to improve the collection and assessment of data on the international scale.

At the 1997 Task Force meeting it was decided that future annual reports from ICP IM would have a more technical character. The report could include some scientific material but also short technical descriptions of recent national activities and publications. Scientific articles should preferably be published in recognized scientific journals. The responsibility for producing annual reports would still lie on the Programme Centre, but more contributions from National Focal Points were welcomed.

The content of the present Annual Report reflects the decisions of the Task Force meeting. The report gives a general overview of the ICP IM activities, the present content of the ICP IM database, and presents results from assessment activities carried out by several collaborating institutes and the ICP IM Programme Centre during the programme year 1997/98. The resources of the Programme Centre have been targeted to the revision of the Programme Manual and the EU/LIFE-project 'Development of Assessment and Monitoring Techniques at Integrated Monitoring Sites in Europe', which has limited the possibilities to carry out additional evaluations of ICP IM data.

Section 1 is a short status report of the ICP IM activities, content of the IM database, including the contents of the GIS database, and the present geographical coverage of the monitoring network.

Section 2 contains a report on multivariate gradient analysis applied to relate chemical and biological observations (prepared by D. de Zwart, RIVM, The Netherlands).

In Section 3 results from heavy metal studies on Swedish IM sites are presented (prepared by L. Bringmark, SLU, Sweden).

Section 4 contains a short summary of the final results of the EU/LIFE-project 'Development of Assessment and Monitoring Techniques at Integrated Monitoring Sites in Europe'. A separate report on the results of this project will be available in July 1998.

1 ICP IM activities, monitoring sites and available data

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1.1 Review of the ICP IM activities in 1997-1998

- The fifth meeting of the Programme Task Force on ICP Integrated Monitoring was held in Dwingeloo (the Netherlands) 23-26 March 1997.

- The revision of the ICP IM manual was a priority in the programme activities in 1997/1998. Two expert groups in collaboration with the Programme Centre prepared a first draft of a revised ICP IM manual, which was presented and discussed at the Task Force Meeting in Dwingeloo, 1997. Suggestions for further changes were made, and the Task Force requested the existing expert groups to include the agreed changes. Thereafter the Programme Centre, assisted by an editorial group, produced a second draft of the manual. This second draft was sent out to National Focal Points and other ICPs for comments in September 1997. The received comments were incorporated to the third draft and this draft was distributed in February 1998. The third draft was approved with certain changes at the Task Force meeting in Tallinn, Estonia, 20-22 April, 1998. The final changes will be made by the Programme Centre in collaboration with the editorial group. The finalized version of the manual will be presented at the next WGE meeting, in August 1998.

- In October 1997 the National Focal Points (NFPs) reported their 1996 results to the IM Programme Centre. The Programme Centre carried out standard check up of the results and incorporated them into the IM database.

- Institutes participating in ICP IM activities in Denmark, Finland, Spain, Sweden and the United Kingdom received funding from the LIFE Financial instrument of the European Union for the project that includes the development of monitoring methods and dynamic modelling activities. The final report from this project will be available in July 1998.

- A dynamic model training session, organized as part of the EU/LIFE project, was held in conjunction with the Task Force meeting in 1997.

- A workshop on field methods, as part of the EU/LIFE project, was held in Asa, Sweden in September 15-17, 1997.

- A workshop on advanced data analysis for modelling and assessment of biogeochemical effects of air pollution in temperate ecosystems, as part of the EU/LIFE project, was held in Spain, October 8-11, 1997.

- The programme centres of ICP IM and ICP Forests continued their close cooperation. This work includes, in particular, harmonization of manuals and identification of possible common monitoring sites. The progress report on this activity will be presented at the next WGE meeting, in August 1998.

- ICP IM will produce, in addition to the new IM Manual, the following reports to the Working Group on Effects, August 1998:
  - Annual Report
  - ICP IM contribution to the joint report on trends
  - Joint report of ICPs and Mapping programme
  - Summary of results from EU/LIFE-project

- The joint report on temporal trends is being prepared by all ICPs and the Mapping Programme.

  ICP IM contributes to this report with data on measured trends in bulk deposition, throughfall and soil water chemistry as well as modelled trends in soil and water acidification. The IM contribution will be based on results presented in the 6th Annual Report and results from the EU/LIFE-project. The IM contribution is prepared by the Programme Centre.

1.2 Activities and tasks prepared for 1998-1999

- Finalisation of the IM Manual and presentation at the WGE meeting (August 1998)
- Participation in the activities of external organisations e.g. EU/NoLIMITS project and GTOS (1998/1999)
- Participation in inter laboratory comparisons organized by other ICPs (1998/1999)
- Preparation of ICP IM parts to the report:'Air Pollution: Past and Future Trends' (1998/1999)
- Arrangement of a joint ICP Waters ICP IM workshop on aquatic biological assessment and monitoring
- Inclusion of quality controlled national data for 1997 into the IM database (October 1, 1998)
- Processing of additional information (background info/site descriptions)

1.3 Activities aimed at future development of the programme

The ongoing preparation of protocols on nitrogen oxides, POPs and heavy metals can probably be finalized and signed during 1999. Thereafter negotiations on new protocols or revision of existing protocols are not expected to take place for a number of years.

So far much of the assessment work within ICP IM has been directed towards site specific acidification processes — input-output and proton budgets, measured and modelled trends. Studies on acidification processes will be reduced, trend analysis of acidity and N parameters will still be included. Expansions in the following fields are planned:

- Synthesis on heavy metal fluxes — state and trends
- Cooperation with other effect-oriented activities, notably ICP Waters and ICP Forests
- Cooperation with other organisations and research projects outside CLRTAP
- Studies on bioindication

1.4 List of published documents and reports 1997/98

Evaluations of international ICP IM data:

Forsius, M., Alveteg, M., Bak, J., Guardans, R., Holmberg, M., Jenkins, A., Johansson, M., Kleemola, S., Rankinen, K., Renshaw, M., Sverdrup, H and Syri, S. 1997. Assessment of the Effects of the EU Acidification Strategy: Dynamic modelling on Integrated Monitoring sites. Finnish Environment Institute, Helsinki. ISBN 952-11-0979-3. 40 pp.

Forsius, M., Alveteg, M., Jenkins, A., Johansson, M., Kleemola, S., Lükewille, A., Posch, M., Sverdrup, H. and Walse, C. 1998. MAGIC, SAFE and SMART model applications at Integrated Monitoring Sites: Effects of emission reduction scenarios. Water, Air and Soil Pollution (In Press).

Forsius, M., Guardans, R., Jenkins, A., Lundin, L. and Nielsen, K.E. (eds) 1998. Integrated Monitoring: Environmental assessment through model and empirical analysis - Final results from an EU/LIFE-project. The Finnish Environment 218 (In Press). Finnish Environment Institute, Helsinki. ISBN 952-11-0302-7. 172 pp.

Kleemola, S. and Forsius, M. (eds) 1998. UN ECE ICP Integrated Monitoring, 7th Annual Report 1998. The Finnish Environment 217, Helsinki. Finnish Environment Institute, Helsinki. ISBN 952-11-0301-9.

Zwart, D. de, 1997 Ordination of the integrated monitoring data gathered under auspicies of ICP-IM (UN-ECE Convention on Long-Range Transboundary Air Pollution): 1998-1994. RIVM report 259101 006.

Evaluations of national ICP IM data:

Ambrosi, P. , Bertolini, F., George, E., Minerbi, S. and Salvadori, C. 1998. Integrated monitoring in alpine forest ecosystems in Trentino and South Tyrol, Italy. Chemosphere 36(4-5): 1043-1048.

Bonavita, P., Chemini, C., Ambrosi, P., Minerbi, S., Salvadori, C. and Furlanello, C. 1998. Biodiversity and stress level in four forests of the Italian Alps. Chemosphere 36(4-5): 1055-1060.

Bringmark, L. 1997: Accumulation of Mercury in Soil and Effects on Soil Biota. In: Metal ions in biological systems (A. Sigel & H. Sigel (eds)). Vol. 34: Mercury and Its Effects on Environment and Biology. New York, Basel, Hong Kong.

Bringmark, E. and Bringmark, L. 1998: Improved Soil Monitoring by Use of Spatial patterns. - Ambio 27:45-52.

Carl, M. 1997 - Biomonitoring Der Zikadenfauna (Auchenorrhyncha) an den Dauerbeobachtungsflächen IT01 Ritten - IT02 Montiggl 1996 Ed. Forest Department - Autonomous Province of Bolzano.

Guardans, R., Palacios, M. and Martin, F. 1997. Variability of lead concentrations in dust in the southwest of the Iberian peninsula. pp 155-171 in World Meteorological Organization/ Global Atmospheric Watch. Report and proceedings of the workshop on the assessment of EMEP activities concerning heavy metals and persistent organic pollutants and their future development, Moscow 24-26 Sept 96. Vol2. WMO/TD No 806.

Huber[1], W. and Aichner[2], M. 1997 - Contents of micro- macroelements and toxic substances in spruce needles at the level 1-2-3 monitoring plots in South Tyrol (co-funded by EU-Reg. 3528/86, 2157/92, 1091/94); [1]- Department 29 - Environment Agency [2]- Office 33.2 Agricultural Chemistry Laboratory of the Laimburg Research Centre Ed. Forest Department - Autonomous Province of Bolzano.

Jeffries, D.S. (ed.) 1997. Canadian Acid Rain Assessment Volume 3: The Effects on Canada's Lakes, Rivers and Wetlands. Department of Environment, 1997. 213 pp.

Kinnunen, T., Hartmann, M. and Starr, M. 1998. Biomass functions for mountain birch in Vuoskojärvi Integrated Montoring area. Boreal Environment Research (Accepted for publication).

Kurka, A.-M. and Starr, M. 1997. Relationship between decomposition of cellulose in the soil and tree stand characteristics in natural boreal forests. Plant and Soil 197: 167-175.

Latvian Hydrometeorological Agency, 1998. Environmental Pollution in Latvia, Annual Report 1997. Latvian Hydrometeorological Agency, Riga 1998.

Liu, Q. 1997: Variation partitioning by partial Redundancy Analysis (RDA). Environmetrics (In Press).

Mathijssen-Spiekman, E.A.M. and Wolter-Balk, M.A.H. 1998 The Integrated Monitoring Area Lheebroekerzand - The Netherlands Data of 1996 RIVM report no. 259102 008.

Meyer, E. 1997 - Die Waldbodenfauna nördlich und südlich des Alpenhauptkammes, Ed. Abhamdlungen und Berichte des Naturkundenmuseum Görlitz, 69, 2:135-150.

Meyer, E. 1997 - Diplopoda aus Barberfallen in Waldstandorten der Auton. Prov. Bozen und Trient, (Dauerbeobachtungsflächen IT01 Ritten - IT02 Montiggl - IT03 Lavazè - IT04 Pomarolo), Erhebungsjahre 1992-1993 Ed. Forest Department - Autonomous Province of Bolzano.

Oja, T., and Arp, P.A. 1998. Assessing atmospheric sulfur and nitrogen loads critical to the maintenance of upland forest soils. In: D.G. Maynard, (ed.) Sulfur in the Environment, Chapter 10, pp. 337-363.

Roots, O. and Saare, L. 1997. Structure and Objectives of the Estonian Environmental Monitoring Programme in 1996-1997. BIOGEMON'97 Villenova University June 21st-25th 1997. Journal of Conference Abstracts, Cambridge Publications, 2, (2), pp. 283.

Roots, O. Saare, L. and Talkop, R. 1997. The state of atmospheric emissions and the air quality transboundary air pollution. Regional Modelling of Air Pollution in Europe (Ed. G. Geernaert, A. Walløe Hansen and Z. Zlatw), proceedings of the first REM APE workshop Copenhagen, Denmark, pp. 131-141.

Roots O. and Talkop R. (eds) 1997. Estonian Monitoring 1996, Ministry of the Environment of Estonia, Environment Information Centre, 168 pp.

Schwienbacher, W. 1997 - Teilbereich Zoologie: Käfer (Coleoptera) an den Dauerbeobachtungs-flächen IT01 Ritten - IT02 Montiggl. Bericht 1992-1996 Ed. Forest Department - Autonomous Province of Bolzano.

Schwienbacher, W. 1997 - Teilbereich Zoologie: Käfer (Coleoptera), Erhebungsjahr 1993 - Untersuchungsfläche IT01 Renon/Ritten Ed. Forest Department - Autonomous Province of Bolzano.

Schwienbacher, W. 1997 - Teilbereich Zoologie: Käfer (Coleoptera), Erhebungsjahr 1993 - Untersuchungsfläche IT02 Monticolo/ Montiggl Ed. Forest Department - Autonomous Province of Bolzano.

Solberg, S. and Tørseth, K. 1997. Crown condition of Norway spruce in relation to S and N deposition and soil properties in Southeast Norway. Environmental pollution 96/1:19-27.

Solberg, S. & Strand, L. 1997. Crown density assessments, control surveys and reproducibility. Environmental monitoring and assessment (In Press).

Solberg, S., Rindal, T.K., Ogner, G. 1997. Pigment composition in Norway spruce needles suffering from different types of nutrient deficiency. Trees. 12: 289-292.

Ukonmaanaho, L., Starr, M. and Ruoho-Airola, T. 1998. Trends in sulphate, base cations, and H+ concentrations in bulk precipitation and throughfall at Integrated Monitoring sites in Finland 1989-1995. Water, Air and Soil Pollution (In Press).
Vanhala, P., Kapanen, A., Fritze, H. and Niemi, R. M. 1998. Microbial activity in four Finnish coniferous forest soils - spatial variability and effect of heavy metals. Boreal Environment Research (Accepted for publication).
Zulka, K.P. 1997 - Die Chilopodenfauna von vier Standorten der Provinzen Bozen und Trient (Italien) - (Dauerbeobachtungsflächen IT01 Ritten - IT02 Montiggl - IT03 Lavazè - IT04 Pomarolo), Erhebungsjahre 1992-1993 Ed. Forest Department - Autonomous Province of Bolzano.

1.5 Monitoring sites

The Integrated monitoring network covers the following twenty-one countries: Austria, Belarus, Canada, Czech Republic, Denmark, Estonia, Finland, Italy, Iceland, Germany, Spain, Switzerland, Latvia, Lithuania, The Netherlands, Norway, Poland, Portugal, Russia, Sweden, and United Kingdom. These countries have either on-going data submission from at least one monitoring site or the data submission is just starting. Location of the IM monitoring sites with on-going data delivery is presented in Figure 1.1 (i.e. data from year 1994 received and/or continuation of the monitoring indicated).

In the database data is available from two additional countries: Hungary and Ukraine. The monitoring activities in Hungary have been suspended and Ukraine has been unable to submit data in the last few years.

1.6 Monitoring data

All in total, integrated monitoring data is at present available from 60 mostly European sites. An overview of the data reported internationally to the ICP IM Programme Centre and presently held in the IM database is given in Table 1.1. This means that data is also available from additional sites outside those presented in Figure 1.1. with on-going data submission. The additional sites have either been suspended or have been taken out of the IM network and used for regional monitoring. E.g. Sweden started with a number of monitoring sites but has since then made a decision to carry out integrated monitoring only on four sites, the other sites have been downscaled to regional monitoring sites. The total number of sites with on-going data submission is 44 (i.e. data from year 1994 received and/ or continuation of the monitoring indicated). Sixteen sites are considered suspended. Two sites; Austrian site and a site on the Faroe Islands will start the data submission soon. Sweden has recently started a fourth site. Italy has included an additional nine sites to the programme, but the data submission has not yet started.

The GIS data available from the IM monitoring sites are presented in Table 1.2.

Geographical location of the Integrated Monitoring sites

Site with on-going data submission

Site with data submission to be started

Table 1.1 Internationally reported data held presently in the ICP IM database.

AREA	SUBPROGRAMME															*							
	AM	AC	DC	MC	TF	SF	SC	SW	GW	RW	LC	FC	LF	RB	LB	FD	VG	EP	AL	MB	BB	BV	Info
	climate	air chemistry	precip. chemistry	moss chemistry	throughf.	stemflow	soil chemistry	soil water chemistry	groundw. chemistry	runoff water c.	lake water c.	foliage chemistry	litterfall chemistry	hydrob. of str.	hydrob. of lakes	forest damage	vegetat.	trunk epiphytes	aerial gr.algae	microb. decomp.	bird inventory	vegetation inventory	
BY02	89-97	89-97	89-97				95-96			95-97													
CA01	88-94		88-94						88-94	88-94													
CH01	88-96	88-96	88-96		91-96				90-96	88-96	-	89			-	95-96							
CZ01	89-96	89-96	89-96	89	89-96					89-96	-				-								
DE01	90-96	90-96	90-96	90	90-96	90-96	90	90-96	88-96	90-96	-	90-96	90-96		-	90-96	90-95	92-95		94-96	91-96	90,95	
DK01			92-96		92		86	92-96		-	-			-	-								
DK03			94-96		94-96		95	94-96		-	-			-	-		95						
EE01	95	94-96	94-96	94	94-96	94-96	94	94-96	95-96	-	-	94-96	94-96	-	-	94-95	94	94-96		94-96		94	
EE02	94		94-96	94-95	94-96	94-96	94-95	95-96	95-96	94-96	96	96	94-96			96	96	94-95	94	96			
ES01			92-93		92-93		92	92-93		91-93	-				-								modelling data
FI01	88-96	94-96	88-96	88-91	89-96	89-96	88-89	89-96		88-96	87-96	88-96	90-95		90-93	88-91	88-95	88-94		90	87-89	87	
FI03	88-96	93-96	88-96	89-91	89-96	89-96	88	89-96		88-96	87-96	88-96	90-95		90	88-91	90-95	90-94		90-91	87-89		
FI04	88-96	89-96	88-96	89-91	89-96	89-96	89	89-96		88-96	86-96	89-96	90-95			89-91	89-95	89-94		90-91	87-89		
FI05	88-96		88-96	91	89-96	89-96	88	89-96		89-96	87-96	88-95	90-95			88-91	89-95	89-94		90-91	88-89		
GB01	88-96	91-96	88-96				90		90-91	88-96	-				-								
GB02	88-96	91-96	88-96		88-91	88-91		90-91		88-96	-				-								
HU01	88-93	88-93	88-93	92-93	90-93	90-93	88		89-93	-	-	92	92-93	-	-								
IT01	93-95	93-95	93-95		93-95	93-95	93	93-95		-	-	93		-	-	92-96		92		93			
IT02	93	93	93-95		93-95	93-95	93	93-95		-	-	93		-	-	92-96		92					
IT03	92-97	93-97	92-97		94-97	94-97	93		95-97	-	-	93	94	-	-	93-97	95	92					
IT04	92-97	93-97	92-97		94-97	94-97	93,95		95-97	-	-	93,95	94	-	-	93-97		92					
IS01																						96	establ. 1996
LT01	93-96	93-97	93-97	93	93-97		93	94-97	93-97	93-95							93-97	93,96	93,96			93	
LT02	93-96	93-97	93-97	93	94-97		93	94-97	93-97	93-95	-			93-97	-		93-97	93,96	93,96			93	
LT03	95-96	95-97	95-97		95-97		94	95-97	95-97	95				95-97			94-97	94,96	94,96			94	
LV01	93-96	93-96	93-96	94	94-96	94-96	94	94-96	94-96	93-96	-	94-96	94-96	95-96	-	94-96	94-95	94-95		96			
LV02	93-96	94-96	93-96	94	94-96	94-96	94	94-96	94-96	93-96	93-96	94-96	94-96	95-96	95-96	94-96	94	94		96			
NL01	93-96	90-96	90-96	93-96	93-96	93-96	93		90-96	-	90-96	93-96	93-96	-	92-96	84-96					90-96		
NO01	87-96	87-96	87-96	92	89-96		86	89-96	87-88	87-96	-	86			-	91-96	86	86					
NO02	87-91	87-96	87-96	88	89-96		89	89-96		87-96	-	89			-	92-96	89						

- Subprogramme not possible to carry out
* or forest health parameters in former subprogrammes Forest stands/Trees

Internationally reported data held presently in the ICP IM database (cont)

AREA	SUBPROGRAMME															*							
	AM	AC	DC	MC	TF	SF	SC	SW	GW	RW	LC	FC	LF	RB	LB	FD	VG	EP	AL	MB	BB	BV	Info
	climate	air chemistry	precip. chemistry	moss chemistry	throughf.	stemflow	soil chemistry	soil water chemistry	groundw. chemistry	runoff water c.	lake water c.	foliage chemistry	litterfall chemistry	hydrob. of str.	hydrob. of lakes	forest damage	vegetat.	trunk epiphytes	aerial gr.algae	microb. decomp.	bird inventory	vegetation inventory	
PL01	88-96	88-96	88-96	88-90	93-96		88	93-96		88-96	88-95	88-90											
PL02				91			90-91				89-90	90-91				90-91	91						
PL03		92-94	93-94		93-94	93-94		91-94		93-94		-	92		-								
PL04	93	93	93-94y		93-94y					93-94y													y=yearly
PT01	88-95	89-96	94-96							90-96	90-96												
RU03	89-94	89-96	89-95																				
RU04	89-94	89-96	89-95	90										93-96		93,96	93	93		94-95			
RU05	89-93		89-93		89-93				90-91	89-93	93					90	90	90					
RU12	93-94	93-96	93-94																				
RU13	93	93-94	93																				
RU14	94	94-96	94-95																				
RU15	90-95	90	90-96	94	90-96	90-96	90		90-96	90-96	-			93	-		91	94					
RU16				89-90			89	89	89						93-96	93-96	91-94	89-94	93	94-95		91	
RU18			92-96	92	92-96	92-96	93	94-96	95-96	92	92-94	92				93	94	93		93			
SE01	83-91		83-94		92-93		82-90	84-95	84-93	84-95			91-92	88-95		87-92	82-93	83-92		83-95		87	
SE02	83-91		83-94		92-93		82-90	85-95	84-94	84-95			91-92	90-95		88-92	82-94	83-92	94	83-95		82	
SE03	83-91		83-94		92-93		88	87-95	85-94	84-95			91-92	91-95		87-92	84-91	84-90		85-95		89	
SE04	87-97	88-96	87-96	95	87-96		95	87-88	79-96	87-96	-				-		95	96	93-95	95-96			
SE05			83-94						83-92	84-95							83-93	83-93					
SE06								85-94	82-94	86-95	-				-		82-91	82-92		84-94			
SE07									82-93		-				-	87-92	82-93	82-92	89-92	83-93			
SE08			83-94						84-94	84-95						88-92	83-93		90-92	84-93			
SE09			88-94						86-92	88-95				87-95		88-94	86-94	86-91	90-94	87-93			
SE10			88-94						88-94	86-95				85-95		88-94	84-94	87-92	89-94				
SE11			83-92						82-94	84-95						88-94	82-94	87-92	89-94	83-93			
SE12			83-94						82-94	84-95						88-94	82-94	82-92	89-94	83-95			
SE13			89-94							89-95	-				-		89-94		92				
SE14	96	96	96	95	96			95-96	96	96	-		95		-		82-92			95-96			
SE15	96	96	96		96			95-96		96	-		95		-		96			95-96			
UA17	90, 93		93																				

Table 1.2 Map data available in the GIS database from individual IM monitoring areas.

CODE	NAME		AREA BOUNDARIES	WATERSHED	PLOTS / STATIONS	NETWORK OF CIRCULAR PLOTS	ELEVATION	LANDUSE	LAKES AND STREAMS	GEOLOGY	SOIL MATERIAL	SOIL TYPE	VEGETATION	TREE SPECIES
AT01	ZÖBELBODEN		X		X			X	X					
BY02	BEREZINA BR													
CA01	TURKEY LAKES/B													
CH01	ERLENTOBEL		X		X		X		X	X			X	
CH02	STABELCHOD		X				X			X			X	
CZ01	ANENSKE POVODI		X	X	X	X	X	X	X	X	X			
DE01	FORELLENBACH		X		X		X		X	X	X		X	
DK01	HJERL HEDE		X		X			X				X	X	X
DK03	HALD EGE		X		X									X
EE01	VILSANDI													
EE02	SAAREJÄRVE													
ES01	PRADES SOR		X	X			X		X			X	X	
FI01	EVO VALKEAKOTINEN		X	X	X		X	X	X	X	X	X	X	X
FI02	EVO MUSTAKOTINEN		X	X	X		X	X	X	X	X	X	X	X
FI03	HIETAJÄRVI		X	X	X	X	X	X	X		X	X	X	X
FI04	PESOSJÄRVI		X	X	X		X	X	X	X	X	X	X	X
FI05	VUOSKOJÄRVI		X	X	X	X	X	X	X	X	X	X		X
FI06	STORTRÄSKET (ÅLGÖ)		X	X	X		X	X	X		X	X		X
GB01	ALLT'A MHARCAIDH		X	X	X		X		X		X			X
GB02	AFON HAFREN		X	X	X		X		X		X		X	X
HU01	MENTELEK (KOMLOSI)		X				X	X					X	
IS01	LITLA-SKARD			X		X			X			X	X	
IT01	RENON-RITTEN		X				X		X				X	
IT02	MONTICOLO-MONTIGGL		X				X		X				X	
IT03	PASSO LAVAZE													
IT04	POMAROLO (SAVIGNANO)													
LT01	AUKSTAITIJA		X	X	X	X			X	X	X	X	X	X
LT02	DZUKIJA		X	X	X	X			X	X	X	X	X	X
LT03	ZEMAITIJA		X	X	X	X				X	X	X	X	X
LV01	RUCAVA		X	X	X		X							
LV02	TAURENE		X	X	X		X		X					
NL01	LHEEBROEKERZAND		X		X				X			X	X	
NO01	BIRKENES													
NO02	KÅRVATN													
PL01	LEKUK		X	X	X		X		X					
PL02	GARDLICZNO MALE													
PL03	RATANICA													
PL04	BRENNA													
PT01	ALENTEJO		X	X				X				X		
RU03	CAUCASUS BR													
RU04	OKA-TERRACE BR													
RU05	JUGA MASSIF													
RU12	ASTRAKHAN BR													
RU13	CENTRAL FOREST BR													
RU14	VORONEZH BR													
RU15	TAYOZHNY LOG (VALDAY)		X		X		X				X		X	
RU16	VELIKIY ISLAND		X		X		X		X		X		X	
RU18	KAMALAHTI		X		X		X		X	X	X	X		X
SE01	TIVEDEN		X	X	X	X	X		X					
SE02	BERG		X	X	X	X	X		X					
SE03	REIVO		X	X	X	X	X		X					
SE04	GÅRDSJÖN F1		X	X	X	X	X		X					
SE05	AMMARNÄS		X	X	X		X		X					
SE06	VINDELN-SVARTBERGET		X	X	X		X		X					
SE07	VINDELN-KULBÄCKSLIDEN		X		X	X	X		X					
SE08	SANDNÄSET		X	X	X	X	X		X					
SE09	STORMYRAN		X	X	X	X	X		X					
SE10	TANDÖVALA		X	X	X	X	X		X					
SE11	TRESTICKLAN		X	X	X		X		X					
SE12	SVARTEDALEN		X	X	X		X		X					
SE13	TOSTARP		X	X	X	X	X		X					
SE14	ANEBODA		X	X	X	X	X		X					
SE15	KINDLAHÖJDEN		X	X	X	X	X	X	X					
UA17	KARADAG		X								X		X	X

Multivariate gradient analysis applied to relate chemical and biological observations

2

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Abstract

This paper contains an exploratory multivariate statistical gradient analysis of possible causes underlying the aspect of forest damage as evaluated by the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM), which is executed under auspices of the UN ECE Convention on Long Range Transboundary Air Pollution.

The results suggest that coniferous defoliation, discoloration and lifespan of needles in the diverse phenomena of forest damage are for respectively 18%, 42% and 55% explained by the combined action of ozone and acidifying sulfur and nitrogen compounds in air.

From the present and previous ordination exercises it can be concluded that the applied statistical techniques are capable of revealing underlying structure and possible cause-effect relationships in complex ecological data, provided gradients are analyzed that are having an adequate range to be interpolated.

Since the data obtained are unexpectedly poor in the span of environmental gradients, the results of the presented statistical ordination only indicate correlative cause-effect relationships with a limited validity.

The poor span of gradients can be attributed to the relative scarcity of biological effect data and the occurrence of missing observations both in the chemical and biological data sets.

2.1 Introduction

Studies of air pollutants acting on particular receptors have often shown that an integrated approach is needed to fully understand the mechanisms of damage and resulting effects on the ecosystem. The International Cooperative Programme (ICP) on Integrated Monitoring (IM) was established in 1992, after a three year pilot programme, to take a more integrated approach to monitoring at selected sites throughout the UN ECE within the framework of the Convention of Long Range Transboundary Air Pollution (CLRTAP).

Two main objectives of ICP IM were defined to comprise:

- The gathering of sufficient data to enable bio-geo-chemical dynamic modeling studies, which should clarify the distribution processes of airborne contaminants both on a continental scale and within specific types of local ecosystems.
- The gathering of sufficient data to reveal cause-effect relationships of air pollution in different ecosystem compartments.

When both main objectives are met and the data are analyzed in concert, the results are expected to be invaluable for the refinement of the concept of critical loads and levels.

In 1995, 23 countries carried out the integrated monitoring programme with 56 sites. Fourteen countries have set the objectives to carry out the full programme at least in one of the chosen national sites. Eight more countries have set the objectives to carry out part of the programme mainly related to biomonitoring aspects. At present no sites are being monitored for the full set of data but many countries are expanding their research programmes to improve on the data reported.

2.1.1 The objective of the present paper

Over the years, the bio-geo-chemical dynamic modeling aspect of pollutant distribution within ecosystem compartments has been treated with considerable detail as can be concluded from a series of Annual Synoptic Reports (EDC, 1994 & 1995; Kleemola and Forsius, 1996).

The analysis of cause-effect relationships as well as effects modeling and effects forecasting, only got some attention over the past few years, as can be deducted from the contributions of Liu in the Annual Synoptic Report 1996 (Liu, 1996) and a few others in the proceedings of a workshop held on this topic in March 1995 (Forsius and Kleemola, 1995).

The continental span of the gradients, which is expected to be available in both biological effects and environmental quality data gathered in ICP IM, forms a unique opportunity for analyzing cause-effect relationships by multi-variate statistical methods, like ordination.

Next to an introduction to the possibilities of multivariate statistical gradient analysis for the extraction of possible cause-effect relationships, this paper is mainly meant to illustrate the utmost importance of the availability of truly integrated data with a high degree of temporal and spatial overlap between environmental variables and biological observations.

2.1.2 The concept of ordination

Ordination (Jongman et al., 1995) is the collective term for multi-variate techniques that arrange sites on the basis of observed similarity in a variety of measured attributes. In ecological research the observed attributes may either be a collection of physico-chemical environmental variables or a collection of response variables, like species abundance or specific biological effects. The result of ordination in two dimensions is a diagram in which sites are represented by points in a two-dimensional scatter diagram. In ordination, the different axes are sequentially explaining a decreasing proportion of residual variance which is not correlated between the axes (orthogonality). Points that are far apart indicate sites that have a high dissimilarity. The exemplary ordination diagram given in Figure 2.1 demonstrates the occurrence of three groups of different sites (•) based on the resemblance of e.g. species composition and abundance.

Figure 2.1 also shows how ordination is used in ecological cause-effect studies. Ecosystems are complex entities: they consist of many interacting biotic and abiotic components and processes. The way in which abiotic environmental variables influence biotic composition or exert their effects on biota is often explored in the following way:

- Given a set of multivariate biological observations from a number of sites, an ordination diagram is made for the detection of similar sites. The ordination diagram is then interpreted in the light of available knowledge on particular preferences of species and established causes of specific effects. Another possibility to demonstrate cause-effect relationships, is to relate the groups of sites in the biological ordination diagram to associated physico-chemical observations. This two-step approach is called **indirect gradient analysis**. With indirect methods of ordination the axes a priori do not have any meaning with respect to environmental variables. The indirect axes are only scaled and oriented to provoke the highest level of separation between sites.

- With **direct gradient analysis**, the biological ordination axes are constructed to coincide with linear combinations of environmental variables. The environmental variables to be used in the calculation should be selected on the basis of indirect ordination or on hypothetically adopted cause-effect relationships.

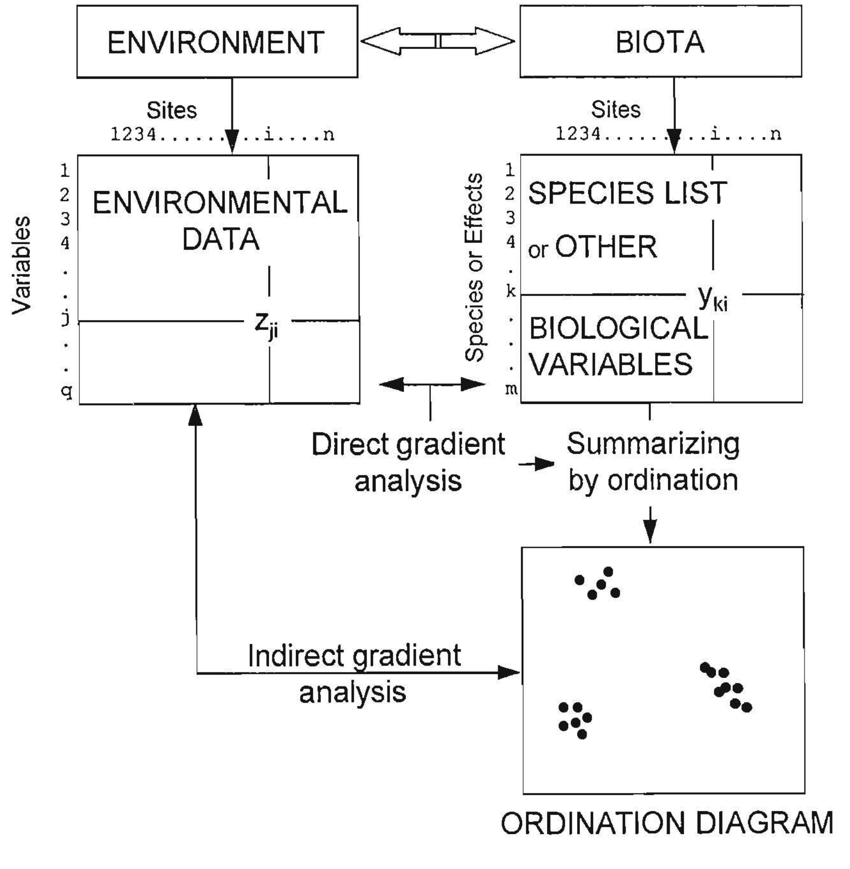

Figure 2.1 Outline of the role of ordination in ecology, showing the typical format of data sets obtained by sampling ecosystems.

Both for direct and indirect gradient analysis there are a few methodologies available, which are mainly differing in the way the biological effects are supposed to respond to the changing environment.

1) With the indirect method, Principal Component Analysis (PCA), and direct methods like Redundancy Analysis (RDA) and Projection to Latent Structure Analysis (PLS), the biological response is considered to be linearly related to all environmental factors as is illustrated in Figure 2.2A for only one environmental variable. These methods are essentially based on linear multiple regression, applied in a reciprocal way.

2) Correspondence Analysis (CA) and Canonical Correspondence Analysis (CCA) are the main indirect and direct methods where the biological response is to have an optimum with respect to the changing environment, as is depicted in Figure 2.2B. The optima are determined by calculating the centroids of species distributions over gradients.

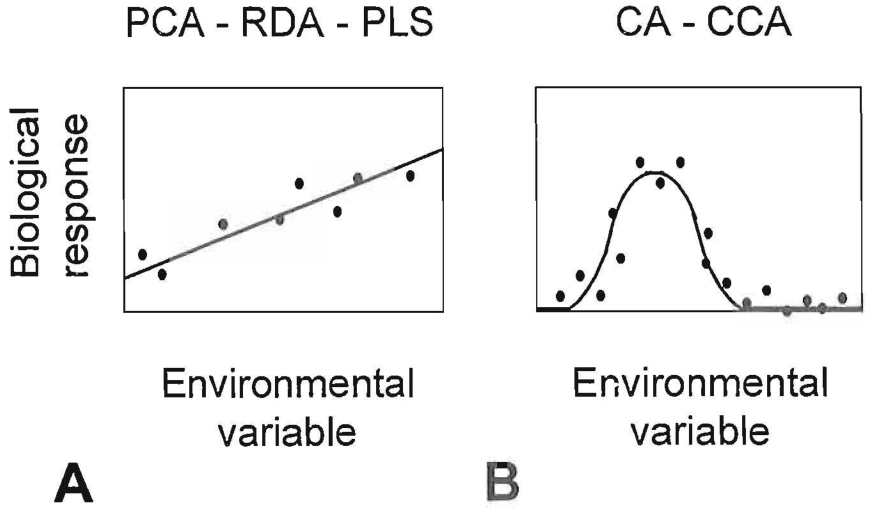

Figure 2.2 The difference between linear and optimum ordination techniques.

In general, species abundance is following optimum criteria with respect to environmental gradients in nutrient levels, soil characteristics, water availability, temperature, etcetera. With respect to toxic or harmful pollution gradients, the response of all organisms is generally resembling log-linearity.

As can be deducted from the data requirements depicted in Figure 2.1, all ordination techniques are extremely sensitive to missing observations.

2.2 Methods

2.2.1 Data selection

De Zwart (1997) made an attempt to assess obvious cause-effect relationships by direct gradient analysis of all of the more or less valid and logical combinations of biological and chemical ICP IM data up to the year 94-95. The following data combinations were tried with limited success:

Runoff water chemistry	vs	River biota
Lake water chemistry	vs	Lake biota
Air chemistry	vs	Forest damage
Precipitation chemistry	vs	Vegetation
Precipitation chemistry	vs	Aerial green algae
Precipitation chemistry	vs	Census of breeding birds

The remaining combinations of environmental pressure and biological effects were either considered to be less plausible or the cause-effect relationship was tried to be analyzed (Vegetation versus Soil chemistry and Microbial decomposition versus Precipitation chemistry) but failed due to a lack of overlapping data. An analysis of the occurrence of Trunk epiphytes versus geographic, climatic and deposition variables has been undertaken by Liu (1996).

During the 1997 ICP IM Task Force meeting it was suggested that the observed lack of data overlap could have been caused by delays and omissions in some of the data being delivered to the ICP IM Data Centre at the Finnish Environment Institute. A thorough reexamination of all data available in 1997 revealed that only the data series for the subprogrammes on forest damage (FD) in combination with the data for air quality (AC), as well as the combination of vegetation surveys (VG) and precipitation-, soil- and soilwater chemistry (DC, SC and SW) were sufficiently extended to allow for renewed ordination exercises. The analysis of cause-effect relationships in the species composition and abundance of vegetation again failed due to a large number of missing data on the level of single observations.

2.2.2 Data preparation

The data were received from the Finnish Environmental Institute as several text files containing one record per line, which were transferred to EXCEL-spreadsheets. By carefully applying the EXCEL-procedure *PivotTable*, it is possible to transform the data to a tabular format where the rows represent variations of the area/date combination and the columns represent the variables. Since in general the biological effects data are reported once or only a few times per year, while the chemical data are reported once or only a few times per year, there is a need for another treatment of the data in order to be able to make statistical comparisons. By removing the month indication from the area/date code, the *PivotTable*-procedure will average the observations per variable over a year. The chemical variables (except pH, temperature and volumetric information) are geometrically averaged by log transformation prior to taking the mean, followed by exponentiation. All other observations are clubbed by arithmetic averaging.

In order to analyze for cause-effect relationships, both chemical and biological data have to be combined into a single spreadsheet. This is accomplished by applying the EXCEL-procedure *Consolidate*, producing a combined table with rows representing all available area/date combinations and columns representing all available descriptions of chemical and biological variables. After this operation rows with non-overlapping or an excess of missing data are removed.

2.2.3 Statistical analysis

For the multivariate statistical data analysis, the program SIMCA-S version 6.0 (Umetri AB, Umeå, Sweden) has been used. Once the combined cause-effect spreadsheets are entered in the SIMCA program, the physico-chemical data are first log transformed (except pH, temperature and volumetric information) and standardized ($x_i^* = (x_i - \bar{x}) / s$) before being assigned the status of predictor (X). The biological data are only standardized before being assigned the role of dependent variables (Y). The SIMCA program is solely operated to analyze assumed linear relationships between physico-chemical and biological data.

The SIMCA program is capable of Principal Components Analysis (PCA) as the first step in indirect gradient analysis, and Projection to Latent Structures (PLS) which is also called Partial Least Squares modeling as a method of direct gradient analysis.

The objective of PCA is to get an overview, or summary of a data table X consisting of several observations on a variety of variables. PCA finds a reduced set of new imaginary variables which are summarizing the X-variables. These so called scores T are linear combinations of the X variables with weights P, called loadings. The loadings show the influence of the original X variables in T. The matrix X is approximated by a matrix of lower dimension (TP) called principal components. To get an overview of the data, a few (1, 2 or 3) principal components are often sufficient. However, for using PCA in predictions, it is essential to extract the maximum number of significant components, which according to preset criteria is performed automatically by the SIMCA program. A PC model can be made much more interpretable by limiting the analysis to the X variables which are having a high relevance to the principal components. The relevance of an X-variable in PCA is indicated by its modeling power, which is related to the explained variance (R2Xadj) of the variable. Variables with a low modeling power are of little relevance and can be removed from the analysis. The scores in different components (t1 vs t2, etc.) can be plotted against each other. These plots can be seen as windows to the X space, displaying the observations as situated on the projection planes of the principal components. These plots may reveal groups of observations belonging together, trends in time or place and outliers. The loadings in different components (p1 vs p2, etc.) plotted against each other, reveal the importance of the X-variables in the analysis. The score- and loading plots complement each other in this respect that a shift of observations in a given direction in a score plot is caused by variables lying in the same direction in the associated loading plot.

PLS finds the linear relationship between a matrix of Y (dependent) variables and a matrix of X (predictor) variables. PLS modeling consists of simultaneous projection of both the X- and Y-spaces on lower dimensional (hyper) planes. The coordinates of the points on these planes constitute the elements of the matrices T(X) and U(Y). The planes are calculated to maximize the covariance or correlation of the observations in the X- and Y-matrices. As with PCA, it is essential to extract the maximum number of significant PLS-components which is related to the predictability (Q2) of dependent data from the independent observations. X- and Y-variables which are irrelevant for the projection can be selected and removed from the analysis based on their fraction of variance explained (R2VXadj, R2VYadj). Internal variance of the Y-matrix can be reduced by removing Y-variables with a low predictability (Q2V(cum)), thereby leaving less residual variance to be explained. For the interpretation of the PLS-results, a number of plots are available:

Score plots	All of these plots will again reveal groups, trends, and outliers	
	t1 vs t2, etc.	These plots are windows in the X-space, displaying observations as projected on the plane of the indicated PLS-components
	u1 vs u2, etc.	These plots are windows in the Y-space, displaying observations as projected on the plane of the indicated PLS-components
	u1 vs t1, etc.	These plots display the observations in the projected X(T)- and Y(U)-space, and show how well the Y-space correlates with the X-space.
Loading plots		
	wc1 vs wc2, etc.	These plots show both the X-loadings (w) and the Y-loadings (c), and thereby the correlation structure between X- and Y-variables, which gives an important clue to extracting cause-effect relationships.

Also with PLS, the score- and loading plots should be interpreted together since a transition of observations in a given direction in a score plot is caused by variables lying in the same direction in the associated loading plot.

The danger of the conclusions drawn from this type of gradient analysis, is that it is fairly tempting to attribute a shift in the effect observations to a confounding predictor variable which is only strongly correlated to the real cause which may not have been measured.

Extracting the maximum amount of information from a particular data set involves the development of a sequence of models in which the data are manipulated by possible transformation of variables and/or removal of irrelevant or unpredictable variables. The model numbers used in the discussion of the different ordination exercises only serve to identify the sequential manipulations to the data set. Graphs and tables with corresponding model numbers are referring to the same data and can be interpreted together.

2.3 Results and Discussion

2.3.1 Air Chemistry versus Forest Damage

Available data

The amount of yearly data available (1991-1996) for the subprogramme forest damage (FD) comprised a total of 40 area/date combinations from Germany, Estonia, Latvia, the Netherlands, Italy, Russia, and Norway. Forest damage has been registered for a total of 12 tree species. The aspects of forest damage which could be handled by the analysis included defoliation (DEFO), foliage discoloration (DISC), tree damage (DAM) and for coniferous species only, the average number of annual needle fascicles per branch (ANF). For the statistical analysis the data for the all forest damage topics have been separately averaged over the coniferous (PIN) and deciduous (DEC) species.

All available air quality (AC) data in the period 1991-1996 consist of 2265 monthly observations from Germany, Finland, Italy, Lithuania, Latvia, the Netherlands, Norway, Russia and Sweden. A total of 10 physico-chemical variables are analyzed. The data have been geometrically averaged over the years.

Combining the 2 data sets and removing area/year combinations which are poor in the coverage of chemical variables or do not have biological observations, as well as removing variables which are not covered by the majority of the remaining stations and variables which do not have any variance over the remaining observations, yields a data matrix consisting of 16 area/year combinations from Germany, Latvia and the Netherlands with six types of forest damage evaluation (ANF-PIN, DAM-PIN, DISC-PIN, DEFO-PIN, DISC-DEC and DEFO-DEC), and measurements of six common physico-chemical variables (In non-filtered air (gas & particulates): NH4N-GP, SO4S-GP and NO3N-GP; and in the gas phase: NO2N-G, O3-G and SO2S-G).

Ordination and interpretation

The relatively limited gradients in the data set and the harmful character of the observed effects are considered to justify the use of log-linear ordination techniques.

A principal component (PC) analysis on the available observations for the chemical predictor variables in air yields a model (M1) with only one significant component with an explained variance equal to about 65%. As can be seen in Figure 2.3 all variables are rather relevant for the ordination.

The same type of analysis with the six variables on damage observed in trees also gives rise to a model (M2) consisting of one dimension. On the basis of unpredictability, the PC is marked insignificant despite the fact that the overall explained variance is a relatively high 51% and all biological variables have a considerable relevance to the model (Figure 2.4).

The chemical and biological data combined into a PLS-analysis forcing the two state-spaces onto a single principal component axis reveals a good fit for the chemical variables with a combined explained variance of 64%, whereas the biological variables do have a much lower explained variance of 29%. The overall predictability of the biological effects from the chemical predictors is zero.

As can be observed in Figure 2.5, this situation is mainly caused by the effect of DAM-PIN, DEFO-DEC and DISC-DEC being unpredictable and having a low relevance to the combined model (see arrows in Figure 2.5).

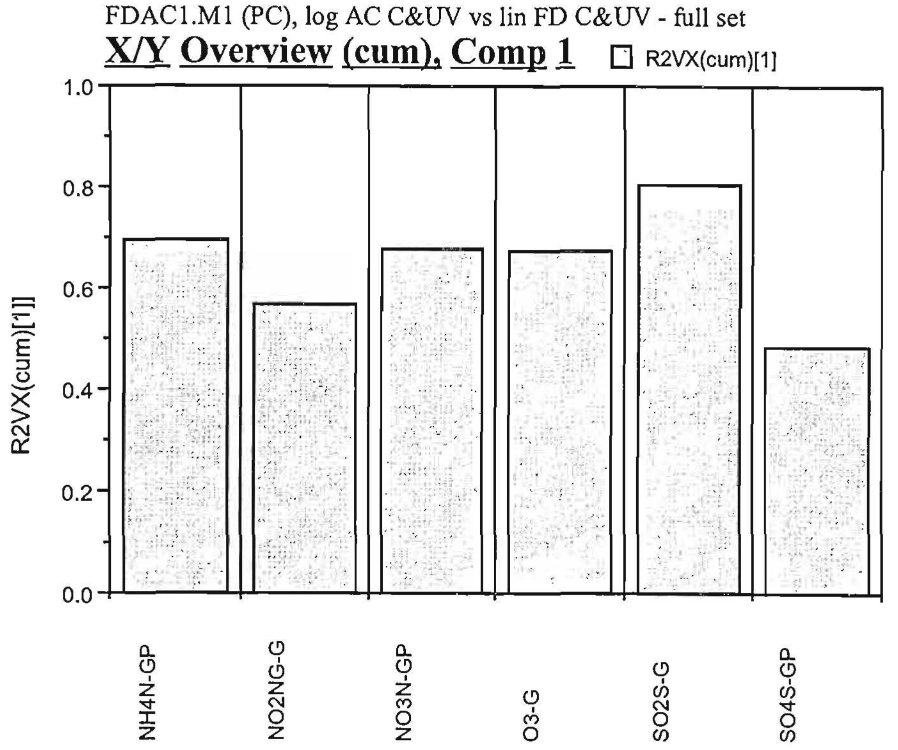

Figure 2.3 Graph demonstrating the relatively high relevance of all chemical variables for the PCX model M1.

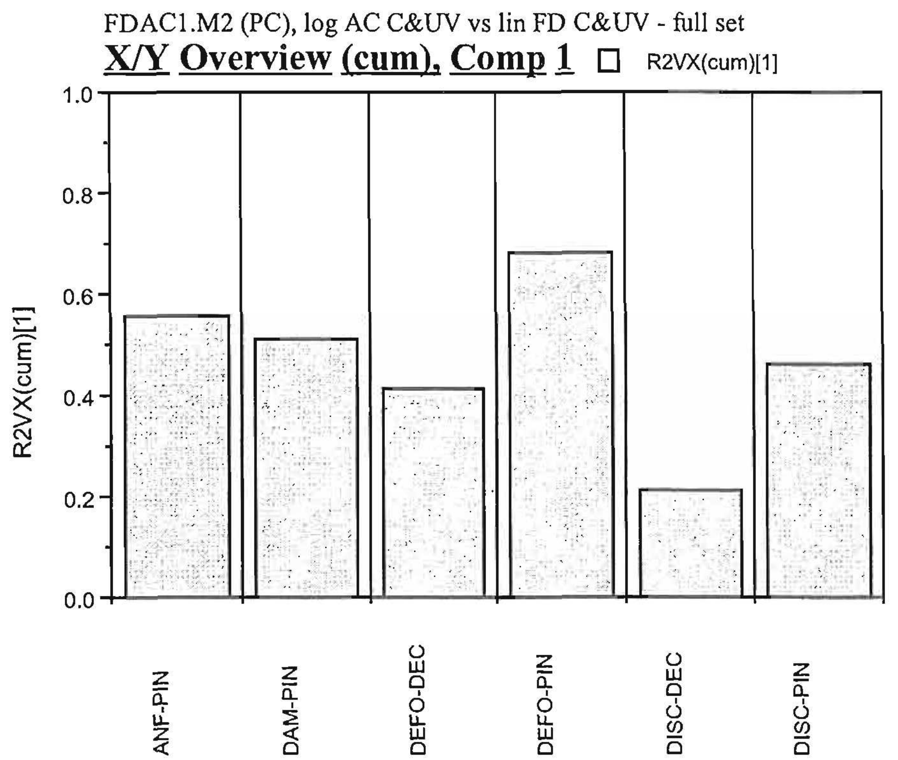

Figure 2.4 Graph demonstrating the relatively high relevance of all biological variables for the PCY model M2.

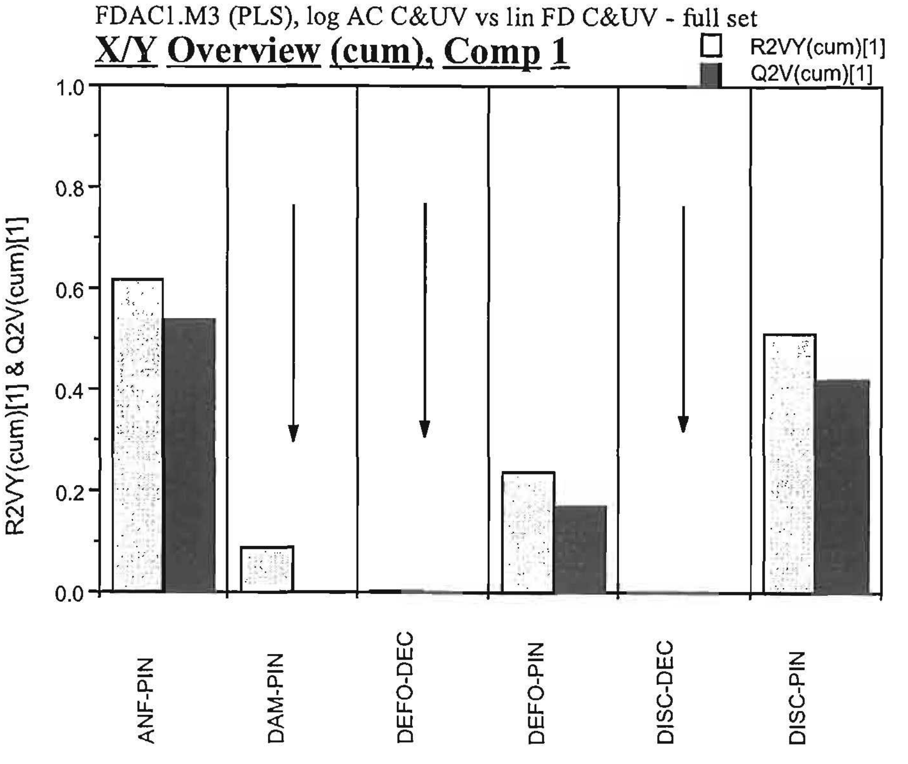

Figure 2.5 Graph demonstrating the low relevance and predictability of the biological variables DAM-PIN, DEFO-DEC and DISC-DEC for the PLS model M3.

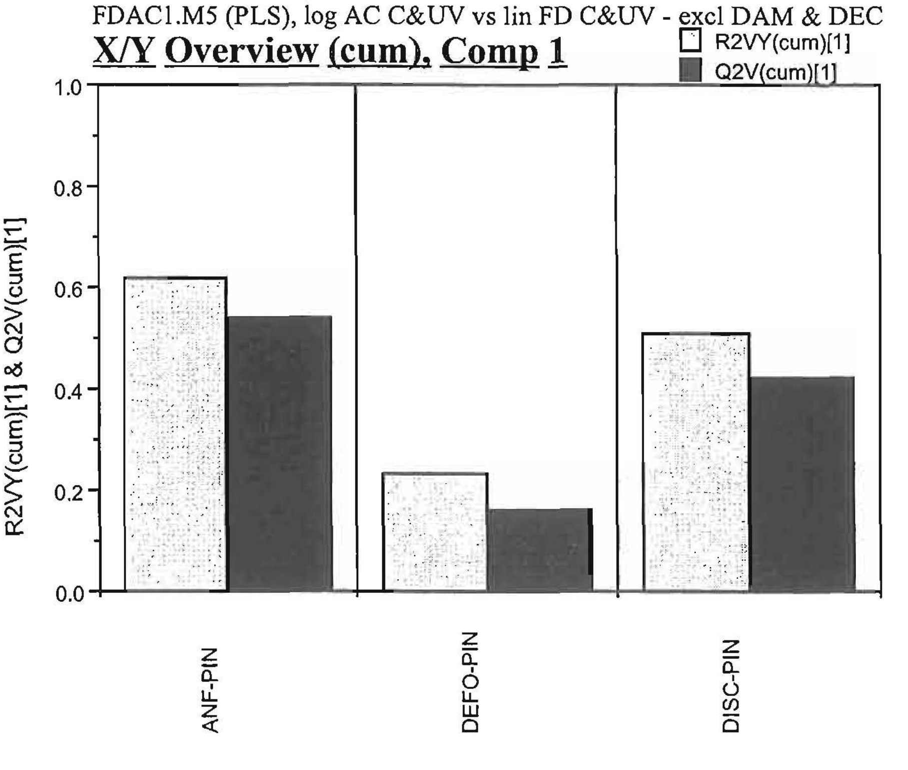

Figure 2.6 Graph demonstrating the high relevance and predictability of the coniferous variables ANF, DEFO and DISC for PLS model M5.

Leaving DAM-PIN, DEFO-DEC and DISC-DEC from the next PLS-analysis (Table 2.1: PLS-M5) generates a one-dimensional model with explained variances of 64% in the chemical data and 44% in the biological observations, together with an overall predictive capacity of 36%.

The quality of this model is illustrated by Figure 2.6 showing the high relevance and predictability of the coniferous data on the variables ANF, DEFO and DISC.

Table 2.1 The overall results of PLS model M5

A	R2X	Eig	R2Y	Q2(cum)
1	0.640	3.838	0.438	0.360

As can be concluded from Figure 2.7, the number of annual follicles per branch (or needle longevity) is highly and defoliation is intermediately positively correlated with the gaseous concentration of ozone. The complex consisting of sulfur and nitrogen compounds mainly in the gas phase displays a high positive correlation with needle discoloration. Ozone and the sulfur-nitrogen complex are negatively correlated. It is highly unlikely that the lifespan of needles is positively influenced by high ozone concentrations. It is therefore concluded that relatively high S/N-concentrations are responsible for a shortened lifespan and an increased discoloration of coniferous needles. A relatively high ozone concentration is mainly concluded to be a possible cause of coniferous defoliation.

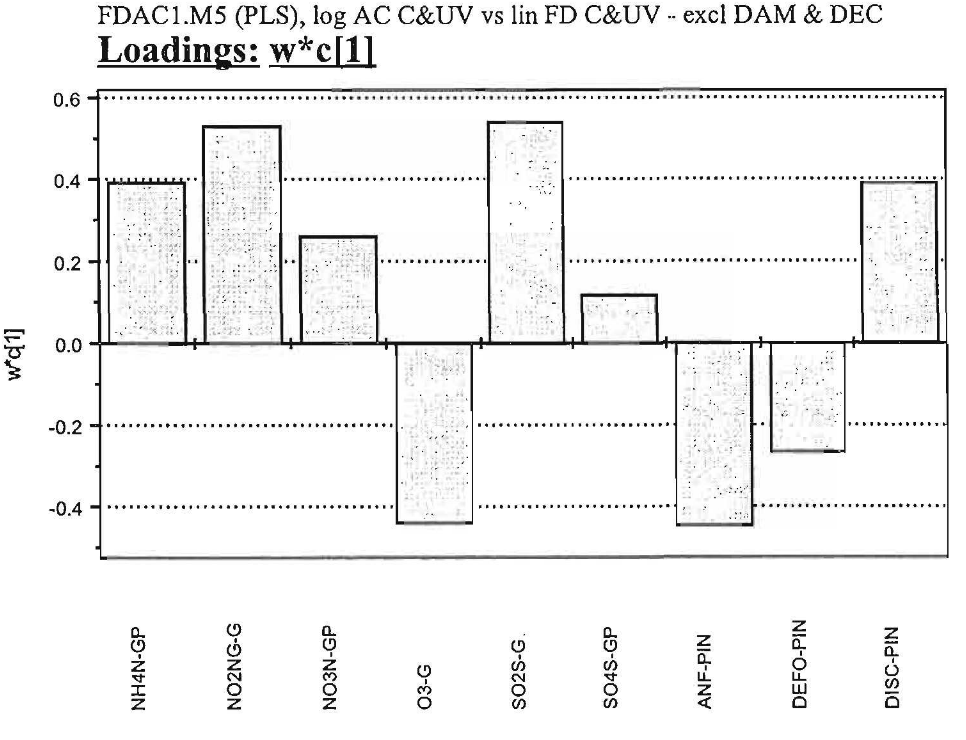

Figure 2.7 The weight or loading of environmental variables and biological effects on the first and only axis of PLS model M5.

Comparing these findings to the results of the same type of analysis previously performed by De Zwart (1997) reveals a partially opposite conclusion with respect to the previously calculated positive correlation of defoliation and the gaseous S/N-complex, which is associated with a negative correlation between defoliation and ozone. However, the results of both exercises are hardly comparable because in the previous exercise it was necessary to average all data on forest damage over coniferous and deciduous species. Furthermore, the quality of the relationships deducted was much lower with an overall predictability of only 8% against 36% in the present analysis.

Figure 2.8 demonstrates the correlation in chemical (t) and biological (u) observations, where, as expected, all observations in the Netherlands appear to be grouped and are deviating from the other observations. Combining the information in Figure 2.7 and Figure 2.8 teaches that the Dutch observations are generally much lower in ozone and higher in the nitrogen and sulfur compounds than the other observations.

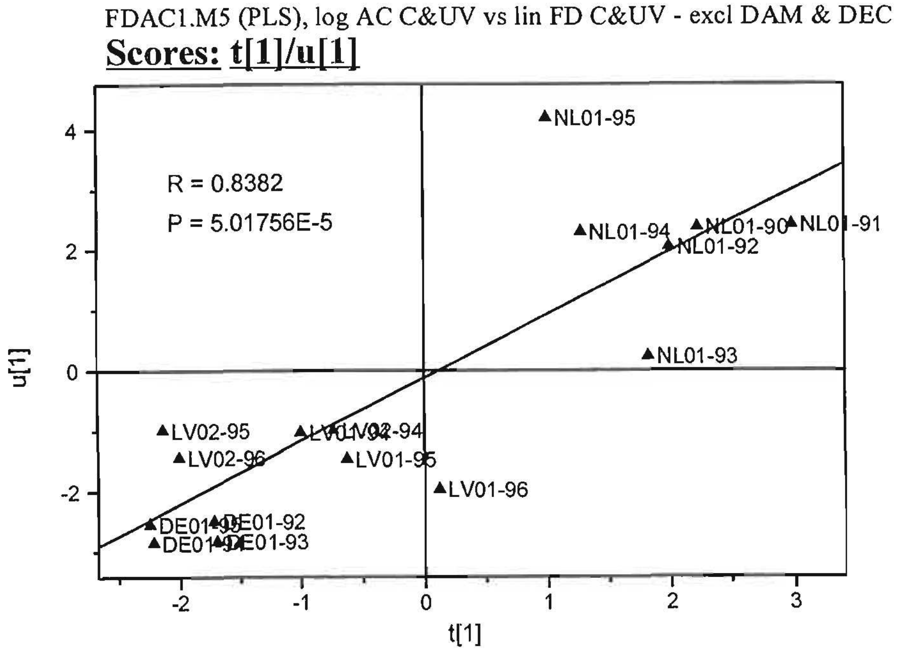

Figure 2.8 The correlation structure on the first and only PLS axis of model 5 between the sites characterized by chemical variables (u) and by biological effects (t).

2.4 General conclusions and recommendations

1) While scanning the combined ICP-IM data set of approximately 180.000 observations, it occurred that some data of the old database (1989-1993) and the new database (1993-1994/1995) were coded in a different way. Furthermore some countries used different codes implying the same variables, especially in the methodological extension to the code of the analyte. This required all data to be reviewed for appropriate coding, before multivariate statistical methods could be applied.

   The enormous amount of time lost in recoding data, clearly illustrates that the success of a complex international monitoring programme is highly influenced by strictly adhering to uniform analytical procedures and to uniform data-formats in reporting.

2) After recoding the data, a start could be made with the analysis, which immediately revealed that subprogrammes related to biological effect variables (even the subjects which are marked "obligatory" for so called "intensive monitoring sites") were only executed at a few of the about 50 stations partaking in the monitoring programme, as is clearly illustrated in the 6 exemplary statistical exercises reported in RIVM-report 259101006 (De Zwart, 1997).

   The lack of biological effects data together with a rather large number of missing observations in both chemical and biological data effectively shortens the span of environmental gradients to be analyzed, thereby reducing analytical resolution as well as the ability to generate effect models with a large scale (continental) validity.

3) Due to the fact that the data obtained are unexpectedly poor in the span of environmental gradients, the results of the presented statistical ordination only indicate cause-effect relationships with a limited validity. The observed relationships are not summarized in the form of multiple regression formulae, since they can **not** be used as a definitive base for estimating critical levels of pollution and large scale forecasting of ecological effects.

4) A total of six different cause-effects relationships have been explored of which only the extended ordination of forest damage has been reported here (c). For the other results the reader is referred to De Zwart (1997).

   a) The ordination trying to explain changes in river biota by changes in river water chemistry fails to do so, most probably due to the fact that the highly dynamic river chemistry is not properly sampled to match the integrative response of river biota.

   b) The ordination of lake biota in relation to lake water chemistry could only be done for the Dutch site. The ordination reveals that the main factors determining community composition in lake biota are not immediately related to the analyzed water quality variables. This may be caused by a time lag in the biological response.

c) The present paper suggests that the aspects of coniferous defoliation, discoloration and lifespan of needles in the diverse phenomenaof forest damage could for respectively 18%, 42% and 55% be explained by the combined action of ozone and acidifying sulfur and nitrogen compounds in the air gas phase.

d) The species composition and species abundance in the Finnish forest vegetation appears to be only partially explained by the chemical composition of precipitation. The most prominent variation of vegetation is most probably related to chemical soil characteristics, which could not be tested due to the absence of data.

e) The occurrence of aerial green algae on the branches and twigs of the tree species *Picea abies* (Spruce), for which data are only available for Swedish sites, proved to be mainly governed by the pH of precipitation. A high pH reduces the coat of algae, the early fall of infested needles and increases the age of the youngest infested shoots.

f) Quite unexpectedly, the species composition and abundance of breeding birds (data available for Finland, the Netherlands and Germany) is to a large extent (72%) explained by the chemical composition and the amount of precipitation. In general most species of birds prefer relatively high values for the observed physico-chemical characteristics. The observed positive relation between bird census and mineral and/or moisture availability is most propably mediated by eutrophication enhanced food supply to the local bird communities.

5) From the ordination results it can be concluded that this type of statistical analysis is capable of revealing underlying structure and major cause-effect relationships in complex ecological data. For the extraction of generally applicable dose-effect models, which are needed to estimate the impact of critical load and level exceedance, the multi-variate approach is considered the only available solution, provided gradients are analyzed that are having an adequate range to be interpolated.

6) As has been specified in the objectives of ICP IM, the programme is designed to cover both aspects of integration:

a) Determination of input and bio-geo-chemical distribution of pollutants in different ecosystem compartments at the same time and place.

b) Determination of ecological effects in relation to local exposure levels.

Due to the fact that the Convention has put considerable emphasis on pollution abatement protocols based on the critical load concept, the analyses executed in the framework of ICP IM were mainly focused on bio-geo-chemical aspects of air pollutant distribution.

Since it is now becoming evident that the internationally adopted emission reduction protocols are likely to lead to a situation where the critical pollutant loads on a continental scale are still locally exceeded, it is becoming more and more important to be able to indicate the ecological impact of critical load exceedance. This can only be accomplished by studying biological effects in combination with local chemical exposure.

The new manual to the UN ECE Integrated Monitoring Programme, which is to be prepared during 1997-1998, has to put emphasis on the need for mandatory integration of chemical and biological data.

Liu (1996; paragraph 5.4.2) also stresses the need for mandatory combining dependent biological and physico-chemical subprogrammes into packages.

Acknowledgments

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3 Heavy metal studies at the Swedish IM sites

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3.1 Regional metal pollution

Metals are components in the complex transboundary pollution in Europe. It is a task for environmental monitoring to follow the fate of these pollutants and to indicate biological effects. The metals recognised as long-range pollutants in Sweden due to pronounced south-north gradients are mercury (Hg), lead (Pb) and cadmium (Cd) (Andersson et al., 1991). The uptake of methyl-mercury in lake fish is a serious problem in boreal landscapes, which requires a systems approach to be understood. It is probable that terrestrial processes to a large degree determine the input of methyl-mercury to the lakes and the fish (Bishop and Lee, 1997).

In earlier investigations of metal effects around point sources, Hg, Pb and Cd were usually not of major concern. When switching the focus to the regional metal problem, we have to deal with these metals and we have to do it at much lower levels than earlier considered to have biological effects. However, given the large scale nature of the problem and the long term accumulation in soils, low-level biological effects may well be of importance and await detection. Of course, it is difficult to identify weak effects in a complex situation, in which many anthropogenic and natural factors coincide. As metals tend to accumulate in the organic humus layer on top of boreal forest soils, this is where the earliest effects should be expected.

3.2 A mass balance for Hg at Tiveden

With the intention to analyze factors determining mercury input to a lake, a detailed study was conducted in the South Swedish IM site Tiveden in 1987 and 1988 (Aastrup et al., 1991). Measurements were made of Hg stored in soil and transports in soil water, ground water and the stream in order to construct a mass balance for Hg (Figure 3.1).

A number of conclusions were drawn from the Tiveden investigation. One was that 75 % of the total Hg flow from the till slope runs through the discharge area as lateral flow through the upper 20 cm of the soil (Aastrup et al., 1991). This was most pronounced when the ground water level was high in spring. Due to seasonal coincidence of high water flows and high Hg-concentrations, a large part of the annual outflow took place in the spring period. The correlation between organic carbon and Hg was not strong in the soil water and ground water, although Hg is generally considered to be linked to organic carbon.

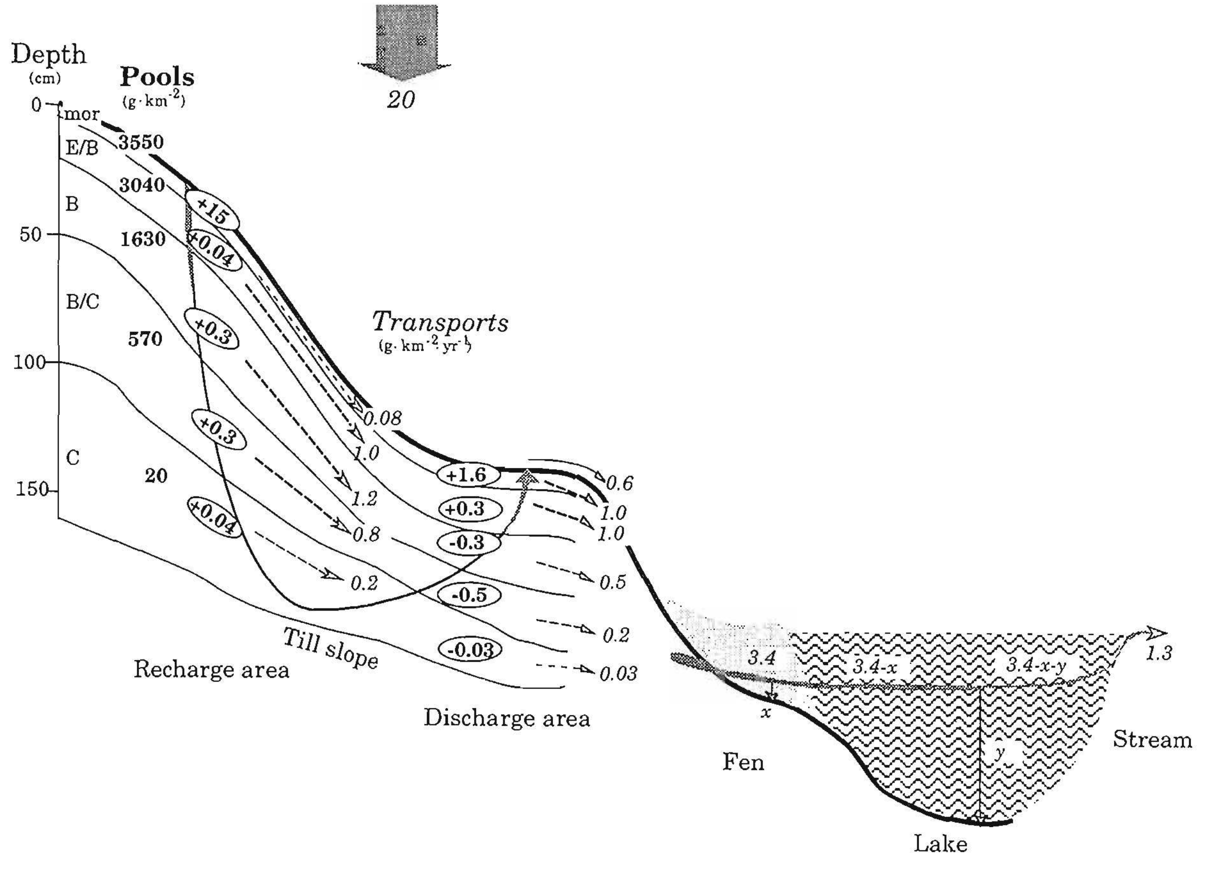

Figure 3.1. Annual Hg budget for a forested slope at the IM site Tiveden. Change of pool sizes is shown within ovals. The terrestrial transports are expressed for the forested area, while the transport from the lake is expressed for the whole catchment including the lake.

Hg mass balances layer by layer in the soil lead to the conclusion that 0.15 g/ha was accumulated in the humus layer annually, which corresponded to 0.4 % of the store. It would have taken at least a century to reach the present Hg store of 36 g/ha of which 25 g/ha was estimated to be the anthropogenic part. By contrast, the accumulation of Hg in the mineral soil was almost negligible. 80 % of deposited Hg was found to be retained in the humus layer and it was concluded that deposition has to be reduced by this degree to prevent further increases in the store (Johansson et al., 1991).

3.3 Sources of uncertainty

There were some major sources of uncertainty in the Tiveden investigation. Many of them have lead to improvements in later programs. We were very concerned by possible contamination or other chemical influences of water samples. A super-clean technique was used for handling collection bottles etc after the samples had passed the lysimeter bodies, that is the porous sampling devices installed in the soil (Aastrup et al., 1991). Many authors are concerned about influence by porous materials on trace metals (Rasmussen et al., 1986, Grossmann et al., 1990, McGuire et al., 1992, Wenzel et al., 1997). Generally, the experience is that ceramic materials retain metals during the passage of solutions, while nylon and other plastic materials do not, although retention may not be a great problem if the material is properly rinsed by acid. However, Hg was not included in the cited tests. A small test that we conducted showed that Hg was not a contamination from the ceramic lysimeters (of type P 80) and that teflon lysimeters yielded higher Hg levels in soil solutions, probably due to passage of organic particles in larger pores. For samples taken in acrylic ground water tubes or in the stream the risk of affecting the sample is not that great.

The wet deposition estimate used in the Tiveden study was based on a general value for South Sweden based on few data and there were no estimates of the dry deposition. At present longer time series for heavy metals, including mercury and methylmercury, exist from four stations within Swedish Precipitation Chemistry Network. Deposition of trace metals is also followed in the throughfall and litterfall in the Swedish IM program during campaigns limited to one year's duration. Dry deposition as well as the wet deposition will to a large extent be covered by these measurements. Litterfall is found to be a large component of the deposition of several metals, especially Hg and methyl-Hg (Bergkvist, 1987, Lee et al., 1994, Hultberg et al., 1995). The demands on clean procedures are, of course, great.

Emission of mercury from soils was ignored in the mass balances for Swedish catchments. This might be an oversimplication as emissions from soils and vegetation might be relatively large for some periods even in our boreal systems (Kim et al., 1997). Uptake of Hg in plants is another process that has been considered negligible for the mass balance (Aastrup et al., 1991), but some unpublished data on the xylem sap of forest trees indicate rather large uptake of Hg in trees. However, it would facilitate the work immensely if emissions and uptake could be ignored in the mass balance.

The measurements during one and a half year at Tiveden was too short to provide reliable assessment of the transports. Much longer series are needed, especially as pronounced seasonal variation was found for Hg in soil water. In the stream runoff continuous measurements of some metals are now routine within the IM program, but for Hg this is done only during campaign years. Longer time series for Hg and MeHg (methyl-Hg) in stream water have been conducted in some research programs (Hultberg et al., 1995). The structure of the hydrological model is another source of uncertainty for the flux assessments as real flow paths might be quite irregular, but it is felt that models should be kept simple to be useful.

The assessment of soil stores is severely hampered by the occurrence of boulders of unknown volume within the soil. Variable soil depths are another major uncertainty, while chemical determinations can be a little less uncertain in spite of large variability.

3.4 Methylation of Hg and identification of controlling factors

Information on Hg transports from a number of catchments in Sweden and North America now makes it possible to start to analyze factors that determine the transport of total Hg (Bishop and Lee, 1997). Chemical methods have allowed monitoring of mercury and methylmercury (MeHg) in water samples for some years now. Both fractions are retained in upper soil layers so that concentrations in percolating water are extremely low further down. In peat formations of riparian zones MeHg might be produced, but total Hg will remain low in the passing solution. Transports of total Hg is controlled by the soluble organic carbon, but MeHg is not. In the period of spring flood in the northern Sweden, all Hg-concentrations were independent of organic carbon. However, high levels of organic carbon are responsible for the comparably large flows at Tiveden (Aastrup et al., 1995). Catchment characteristics rather than deposition determine the outflow of Hg (Bishop and Lee, 1997). But ultimately, in the very long time perspective, Hg outflow is determined by the atmospheric deposition that has formed the soil store.

3.5 Mass balances for Pb and Cd

Similar mass balances as for Hg were also established for Pb and Cd in the Tiveden catchment based on the same data set from 1988 (Figure 3.2). Pb accumulated to less degree than Hg, outflow was rather great even in spite of highly reduced deposition (Aastrup et al., 1995). The soil store of Pb is immense and has probably accumulated during longer time than the mercury store. 56 % of deposited Pb was retained in the soil, compared to 80 % for Hg and only 17 % for Cd. As might be expected, Cd is highly mobile in the soil. The rather high mobility of Pb in relation to the present deposition is interpreted as loss from a store that was formed at higher deposition.

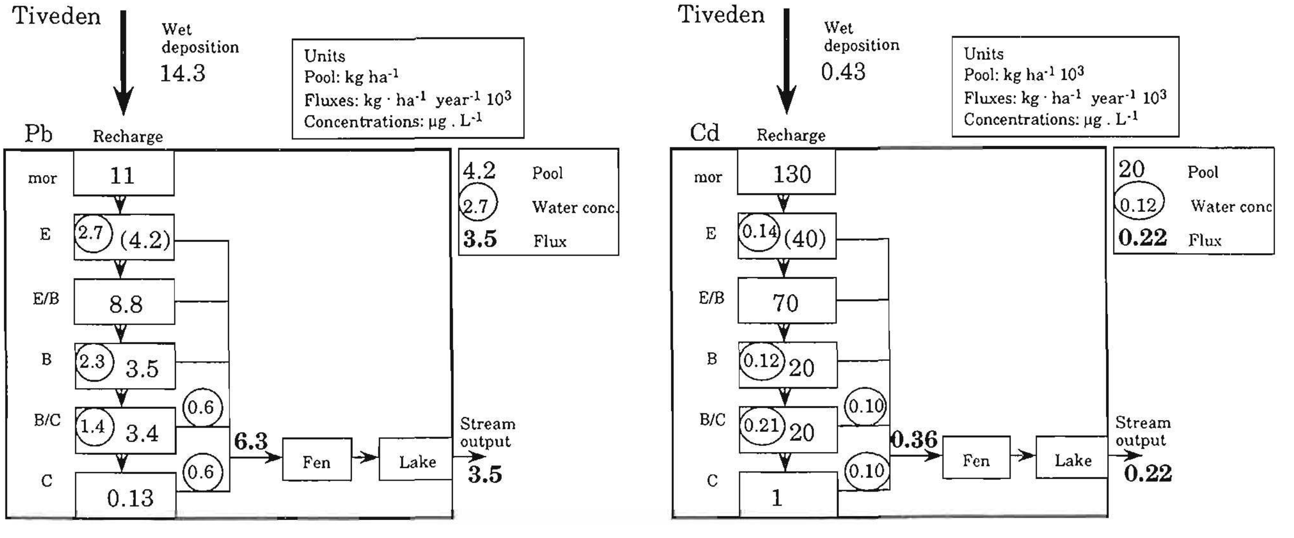

Figure 3.2. Soil storage, concentrations in soil water and ground water and fluxes of Pb and Cd at the IM site Tiveden.

3.6 Regional effects on soil biology

Spatial variability is a characteristic feature of soils and the ecological implications of this would in itself warrant further studies. In making a description of the small scale variation in the mor layer of a 50 by 50 meter soil plot at the IM site Aneboda we found negative correlation between standard respiration at 20 °C and concentrations of Pb and Hg (Figure 3.3). The standard respiration is a very simple, yet sensitive, measure of potential microbial activity, i e activity that can be supported by the substrate quality. Hg and Pb were correlated with each other making it impossible to separate their respective relations to standard respiration. Cd was unrelated to respiration and the other metals. The correlation between Pb, Hg and respiration was taken as indication of biological effects. However, as many factors could influence the mor layer in the small scale, the observed relation is no final proof of metal effects.

A research program was initiated to determine if regional levels of Pb and Hg caused by long-range pollution are of significance for soil microbial activity. This research includes an inventory of the relationship of Pb and Hg to respiration in a number of South Swedish soil plots, in-depth investigation of a large number of factors in a few plots and experiments with addition of Pb and Hg at the relevant low levels. The results will be reported in 1998.

Among other things we found that spatial variability of pH in mor layers of South Sweden was clearly lower at sites subject to high levels of the regional pollution (Bringmark and Bringmark, 1995). The spatial structure obtained by geostatistical calculations was also different. Pb in the humus layer was the most probable pollution variable to cause such effects.

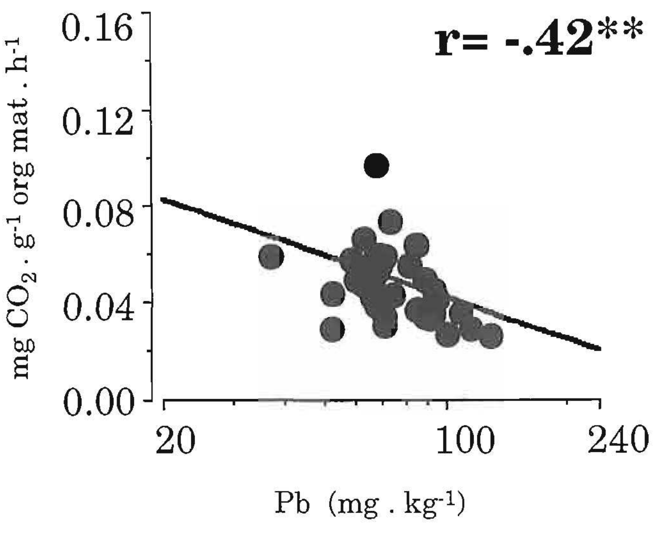

Figure 3.3. Correlation between Pb concentrations and standard respiration in samples from the upper part of the mor layer in a 50 x 50 m soil plot at the IM site Aneboda. 36 samples were taken at 10 meters intervals.

3.7 Use of Integrated Monitoring for pollution assessments

The descriptions of mass balances for metals in forest systems were made by use of data from integrated monitoring programs in small catchments (Aastrup et al., 1991, Aastrup et al., 1995). The first indications of biological effects in humus layers from background areas were also based on observations in the IM program. This was a basic starting-point for the formulation of scientific questions. However, to pursue the case further additional research programs were necessary. Factors determining transports of total mercury as well as mercury methylation were studied by monitoring for some time in selected catchments outside the monitoring program with characteristics that would optimize the understanding (Bishop and Lee, 1997). The large roof experiment, in which an entire catchment has been sealed off from pollution is another important project, which is paired with the IM site at Gårdsjön, the latter used as reference (Hultberg and Skeffington, 1998).

A large research program at the Swedish Environmental Protection Agency is now at a final stage (Bergbäck & Johansson, 1996). In this program budgets of Hg, Pb and Cd for catchments at IM sites are described in a detail that could not be financed within the monitoring program alone. An inventory of soil metal levels in a large number of sites in the National Forest Survey is also financed by the research program. The investigations of effects on microbial activity in humus layers described above will, if possible, provide proof of biological effects caused by long-distance pollution. The strategy for the latter research includes comparisons of properties of soil plots in a pollution gradient across South Sweden (Bringmark and Bringmark, 1995) and laboratory experiments with low level doses of Pb and Hg. Thus, some research activities are direct supplements to the monitoring programs, while others go further to effectively answer questions that have been aroused.

What is the role of Integrated Monitoring in the future work? At present there are initiatives to develop critical loads for Pb, Cd and Hg (UN-ECE, 1997). Hg seems to be a special Nordic concern in these discussions due to our sensitive aquatic systems, but we suspect that Hg could be a neglected soil pollution in other countries. The information gathered in the Swedish monitoring and research programs is well suited for mass balance models and effect-based criteria of use in the Critical Loads development. However time series for mercury and other metals in litterfall, soil water, ground water and runoff are still short and should be extended in time. It is of special interest to follow changes that might follow from the reduced pollution loads during the last decades. The method of Integrated Monitoring to collect various kinds of data within well-defined catchments will ensure that maximum information is gained from the measurements, bearing in mind that heavy metals are expensive and difficult to sample and determine.

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Summary of final results from the EU/LIFE-project

4

4.1 Background, aims and implementation of project

Changes in the composition of the atmosphere with consequent global climate change and regional air pollution may have a profound impact on the structure and function of both terrestrial and water ecosystems. The air pollution problem consists of a complicated matrix of compounds and effects, in which the control of one compound will influence the transport and effects of others. Thus, an assessment of the overall present and future impacts of atmospheric change requires knowledge about the emissions causing the change, the processes controlling the change in the environment, as well as about the environmental effects resulting from these changes. Very large costs are presently associated with the implementation of air pollution control measures, and it is essential that relevant ecosystem monitoring systems, techniques and results are available for assessing the effects and efficiency of these investments.

The EU/LIFE-project 'Development of Assessment and Monitoring Techniques at Integrated Monitoring Sites in Europe' was carried out during 1996-97 by several institutes participating in ICP IM, and data collected at the IM-sites was used in the different subprojects. The project received funding from the Financial Instrument for the Environment (LIFE) of the EU (project LIFE95/FIN/A11/EPT/387). The key aim of this LIFE-project was to develop methods and carry out evaluations which can be used for the assessment and monitoring of the ecosystem effects related to the implementation of international air pollution policy.

The project had a multidisciplinary scope and encompassed the development of empirical ecosystem monitoring and assessment methods, dynamic modelling, and impact scenario assessment. Institutes from Denmark, Finland, Spain, Sweden and UK participated in the work. The project was coordinated by the Finnish Environment Institute. The main results of the project are summarised in Forsius et al. (1998). The structure, financing, implementation and dissemination activities of the project are described in more detail in the final management report of the project (Final Report 1998). For many of the subprojects also more detailed technical descriptions are available.

The development of empirical monitoring methods and assessment techniques concerned the following topics:

- development of a GIS database and interface
- development of a dry deposition sampler
- enhancement of forest growth and nutrient uptake estimates
- development and comparison of techniques for soil water sampling
- methods for assessing nitrogen fluxes and processes in catchments
- weathering rate and ion exchange estimates for groundwater modelling
- mass balance studies and sulphate retention estimates
- plant indicator values for indicating vegetation changes

The following modelling and scenario assessment tasks were carried out as part of the project:

- development of models for the derivation of deposition scenarios
- derivation of site-specific deposition and nutrient uptake scenarios
- site-specific applications of complex mathematical acidification models
- application of a regional-scale lake acidification model
- assessment of the effects of emission/deposition scenarios
- assessment of model uncertainties
- site-specific application of a model for assessing forest growth
- development and site-specific application of an energy-balance (SVAT) model
- assessment of the effects of climate change scenarios on hydrological properties

The emission/deposition scenarios were based on the proposed EU Acidification Strategy (COM(97)88/4) and current emission reduction plans related to the UN/ECE Convention of Long-Range Transboundary Air Pollution (CLRTAP).

4.2 Key results, conclusions and recommendations

General

The integrated ecosystem monitoring concept has a central role to play in the provision of data and information required support to the multidisciplinary approaches for the detection and interpretation of regional and global environmental change. Several such new tools and approaches have been developed and documented in the LIFE-project. These new concepts can be used in the ICP IM framework or in other national and international monitoring networks, where adequate information is available.

Mathematical models are the only available tools that allow the assessment of future dynamic responses. A linked model system was developed and applied to site-specific and regional-scale data, and the calibrated model versions were used to assess the effects of different impact scenarios. The applications demonstrate how models can be used in a policy-oriented framework to explore consequences of the magnitude and timing of emission reductions and effects of climatic change. These results complement the calculations of regional-scale (steady-state) critical loads.

The effects of emission reductions on the catchment scale were evaluated using scenarios based on the EU Acidification Strategy and UN/ECE protocols. The transient responses of soil base saturation, stream water pH and ANC, integrated on the catchment scale, were predicted with the models MAGIC, SAFE and SMART (and their extended versions). An application with the Direct Distribution model using regional-scale lake data was also carried out. The linked model system is flexible and can be adjusted for the assessment of other alternative scenarios of policy importance.

Key findings

1. The use of GIS as a storage and analytical tool in environmental monitoring and assessment is continuously increasing. The results from the GIS-database development showed how heterogenous cartographic information can be stored in a consistent framework, thus greatly facilitating the use and transfer of the data.

2. The use of surrogate surfaces to quantify true dry deposition in forests and separate this from internal circulation of elements as they appear in throughfall is a powerful tool to evaluate changes and sources of air pollution. The method is inexpensive and needs no electricity.

3. Biomass functions and growth and succession models can be efficiently applied for the quantification of forest growth and the associated soil acidification. Forest growth models which include climate factors can also be used to simulate the acidification effect of various climatic change scenarios.

4. The ability to collect horizon-specific gravitational water is important for the understanding of processes for nutrient release. Soil water sampled by suction lysimeters does not reflect the seasonality of leaching processes. Gravitation lysimeters seem to catch the macropore-flow which is highly dominant in the coastal heath soil. There are large differences between sampler types also concerning water yield as well as lead and cadmium concentrations.

5. The piezometer technique for soil and ground water sampling is simple, cheap and causes a minimal disturbance. It can be recommended for gradient studies when a large number of samples is needed. The large spatial variation in the concentrations of nitrogen species and DOC in the ground water and soil water indicates that a large number of samples is needed to describe the nitrogen dynamics in the near-stream zone.

6. Simple monitoring methods already implemented in the IM-programme, such as chemical determinations in suction lysimeter leachates and pH measurements in humus layer, are adequate to pick up small early effects of nitrogen treatments.

7. Adequate simulation of the chemical composition of superficial groundwater requires further improvements of the presently available biogeochemical models and the data used in their parametrization. Information from one single sampling depth is generally insufficient for modelling assessments and different grain fractions should be analysed. The gravel fraction is probably more important for the calculation of weathering rates and for effects on the groundwater chemical composition, than often considered.

8. Modified sensitivity values for a number of plant species were established, providing a useful tool for biological indication of acidification effects. A better plant indication was provided by the full array of species with sensitivity values on a plot than by a few indicator species. The sensitivity values can be used for the long-term monitoring of vegetation changes in natural ecosystems.

9. Increased knowledge of the response of temperate ecosystems to air pollution is relevant for the development of international air pollution abatement policies. The mass balance studies carried out at the Spanish Sor catchments showed that the principal mechanisms acting to neutralize acidity and maintaining water quality are sulphate retention, mineral alteration and to a much lesser extent cation exchange. Land use history is of key importance for the assessment of the current state of the ecosystems.

10. Improved field and laboratory monitoring techniques and model applications have established the Spanish lake Redó site as a high mountain integrated monitoring observatory for determining regional background levels of air pollution and an early warning system to detect its effects.

11. The DAIQUIRI, CALLUNA and DEPUPT models provide a method to translate the emissions of the EU Acidification Strategy and UN/ECE protocols to changes in atmospheric deposition to individual monitoring sites. In the year 2010, the annual deposition of sulphur is much lower for most sites with the Joint Optimization scenario than with the Reference scenario. The Maximum Feasible Reductions scenario infers for all sites clearly lower 2010 deposition of both sulphur and nitrogen oxides than the Joint Optimization or the Reference scenario. The cumulative deposition load varies greatly between the sites.

12. The MAGIC, SAFE and SMART model results showed that with the Maximum Feasible Reductions and the Joint Optimization scenario, the response variables (base saturation, pH, ANC) stabilize earlier and attain a higher level than with the Current Reduction Plans and the Reference scenarios. At the least acidified sites (DE01 and FI03) the temporal response of the ecosystem to the Joint Optimization scenario is quite similar to that of the Reference scenario. At the UK, Norwegian and Swedish sites, the Joint Optimization scenario leads to an earlier and more pronounced improvement, compared with the Reference scenario.

13. Over a shorter time scale, up to 30 years, the timing of emission reductions determines the rate of recovery. The quicker the target level of reductions is achieved, the more rapid the surface water and soil status recovery. The net effect of extending the target year is to increase the deposition flux to each site, resulting in a delayed response, particularly at the most acidified sites.

14. For the long-term response (> 30 years), the magnitude of emission reduction is more important than the timing of the reduction. The advantage with a stringent strategy is thus twofold, it gives faster response and leads to a better environmental status in the long-term perspective.

15. The MAGIC-WAND simulations indicate that N emission controls are extremely important to enable the maximum recovery in response to S emission reductions. Nitrogen breakthrough has the potential to not only offset the recovery predicted in response to S emission reductions but further to promote substantial deterioration in pH status of freshwaters and other N pollution problems in some areas of Europe.

16. SMART model results showed, that the assumptions regarding nutrient uptake by the vegetation have a significant impact on the conclusions regarding emission reductions especially at low-deposition sites.

17. The Direct Distribution model allows the assessment of regional-scale effects with limited input data requirements. For the Spanish lake data set the Current Reduction Plans scenario would lead to a recovery of original alkalinity values. For the Finnish data set more stringent measures would be required.

18. The ASTIM model allows the assessment of physical processes such as evapotranspiration, surface energy fluxes and soil temperature in the soil-plant-atmosphere system. An arealised model version was also developed. The model results indicated clear changes in key variables such as evapotranspiration for policy-oriented scenarios of climate change at the Finnish IM test site.

Key topics for further work would include:

- Continued effort to improve data collection and harmonisation of IM data at the international scale.
- Improvement and harmonisation of methods for assessing pool sizes and fluxes of carbon, nitrogen and sulphur in forest ecosystems.
- Further efforts to determine controls of carbon, nitrogen and sulphur processes in soils.
- Improvement and harmonisation of methods for assessing biological responses.
- Development of environmental impact indicators.
- Assessment of new impact scenarios of policy relevance, including further assessment of the timing of emission reductions.
- Improvement of N process descriptions in the simulation models, and re-assessment of S scenarios coupled with N deposition scenarios
- Assessment of integrated effects of deposition, climate change and land use management.
- Development of regionalization techniques.

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Publikationens delar/ andra publikationer inom samma projekt	
Sammandrag	Programmet för Integrerad miljö-övervakning (ICP IM) är en del av monitoringsstrategin under UN/ECE:s luftvårdskonvention (LRTAP). Syftet med ICP IM är att utvärdera komplexa miljöförändringar på avrinningsområden. Rapporten sammanfattar de utvärderingar som gjorts av ICP IM Programme Centre och de samarbetande instituten under programåret 1997/98. Rapporten innehåller: - ett sammandrag av programmets nuvarande omfattning och innehåll av IM databasen - en statistisk analys av sambandet mellan kemiska och biologiska observationer - resultat från tungmetallstudier från IM områden i Sverige - ett kort sammandrag över resultaten från EU/LIFE-projektet 'Development of Assessment and Monitoring Techniques at Integrated Monitoring Sites in Europe'.
Nyckelord	Integrerad miljö-övervakning, ekosystem, små avrinningsområden, dynamisk modellering, luftföroreningar
Publikationsserie och nummer	Miljön i Finland 217
Publikationens tema	Internationellt samarbete
Projektets namn och nummer	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
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Kuvailulehti

Julkaisija	Suomen ympäristökeskus — Julkaisuaika: Kesäkuu 1998
Tekijä(t)	Sirpa Kleemola ja Martin Forsius (toim.)
Julkaisun nimi	7th Annual Report 1998. UN ECE Convention on Long-Range Transboundary Air Pollution. International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems.
Julkaisun osat/ muut saman projektin tuottamat julkaisut	
Tiivistelmä	Yhdennetyn seurannan ohjelma (ICP IM) kuuluu YK:n Euroopan talouskomission (ECE) seurantaohjelmiin. Yhdennetyn seurannan ohjelmassa selvitetään kaukokulkeutuvien saasteiden ja muiden ympäristömuutosten vaikutuksia elinympäristöömme. Muutosten seurantaa ja ennusteita muutosten laajuudesta ja nopeudesta tehdään yleensä pienillä metsäisillä valuma-alueilla, mutta verkostoon kuuluu myös muita alueita. *Tässä raportissa esitetään sekä ohjelmakeskuksen että yhteistyölaitosten tekemien arviointien* tuloksia ohjelmavuodelta 97/98. Raportti sisältää: - koosteen IM ohjelman toiminnasta, kuvauksen seurantaverkon laajuudesta ja ICP IM datapankin sisällöstä - tuloksia IM ohjelmassa mitattujen kemiallisten ja biologisten muuttujien suhteiden selvittämisestä moniulotteisen gradientti-analyysin keinoin - tuloksia raskasmetallitutkimuksista Ruotsin IM alueilla - koosteen EU/LIFE projektin 'Development of Assessment and Monitoring Techniques at Integrated Monitoring Sites in Europe' tuloksista.
Asiasanat	Yhdennetty ympäristön seuranta, ekosysteemit, pienet valuma-alueet, dynaaminen mallintaminen, ilmansaasteet
Julkaisusarjan nimi ja numero	Suomen ympäristö 217
Julkaisun teema	Kansainvälinen yhteistyö
Projektihankkeen nimi ja projektinumero	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
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The Integrated Monitoring Programme (ICP IM) is part of the Effects Monitoring Strategy under the UN ECE Convention on Long-Range Transboundary Air Pollution. The main aim of ICP IM is to provide a framework to observe and understand the complex changes occurring in the external environment.

This report presents results from assessment activities carried out by several collaborating institutes and the ICP IM Programme Centre during the programme year 1997/98 including:

- a short status report of the ICP IM activities, content of the IM database, and the present geographical coverage of the monitoring network

- a report on multivariate gradient analysis applied to relate chemical and biological observations

- results from heavy metal studies at Swedish IM sites

- a summary of the final results of the EU/LIFE-project 'Development of Assessment and Monitoring Techniques at Integrated Monitoring Sites in Europe'.

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